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(56) Documents Cited

GB 2204742 A GB 2172443 A EP 0212552 A2  
US 4625135 A

(58) Field of Search

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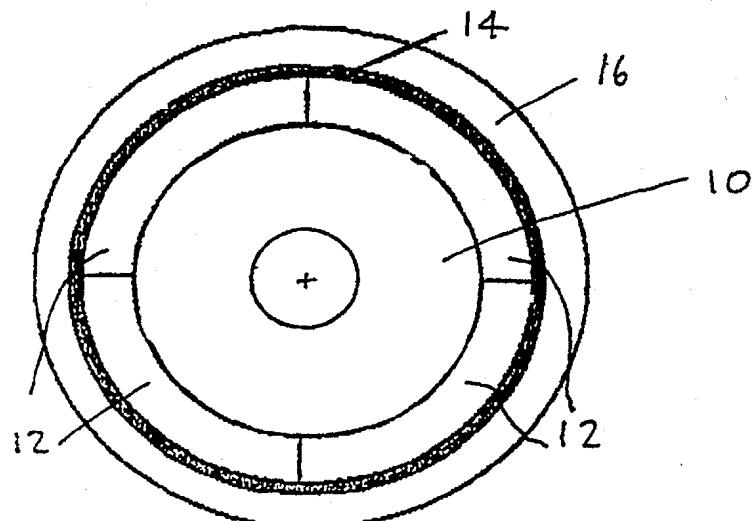
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## (54) Permanent magnet rotor with metal sheath

(57) A permanent magnet motor comprises a rotor having a cylindrical core 10, a plurality of permanent magnets 12 formed from rare earth high energy materials mounted to the surface of the cylindrical core 10, and a metal layer applied to the surface of the rotor over the permanent magnets 12. The metal layer may comprise an inner layer 14 formed from a magnetically permeable material, and an outer layer 16 formed from a highly conductive material, or may be wholly formed of non-magnetic or magnetic material.



## Figure 1

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The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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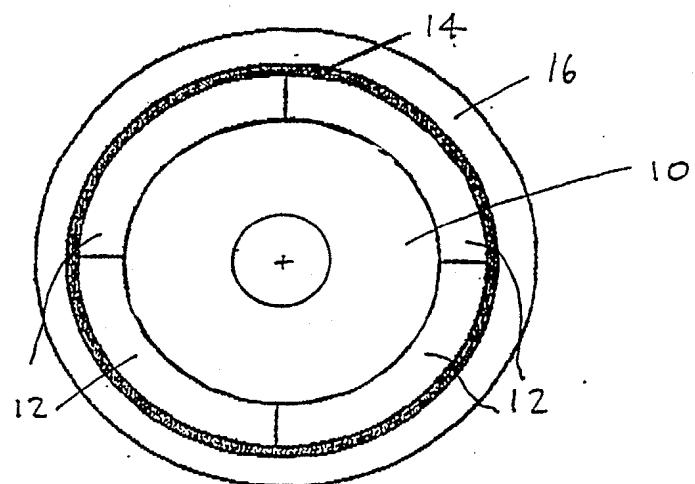


Figure 1

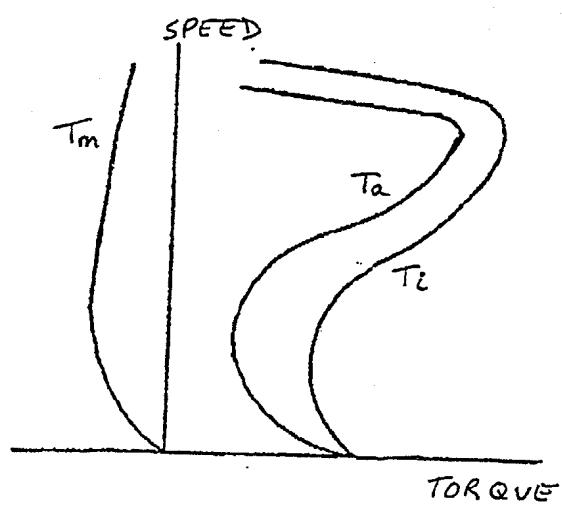


Figure 2

PERMANENT MAGNET MOTOR

This invention relates to a permanent magnet electric motor which may be used as a self-starting (or line-starting) synchronous motor and/or as a high-speed synchronous motor.

There have been a number of proposals in recent years for permanent magnet line-start synchronous motors, following increasing requirements for high efficiency electric drives and the development of high energy permanent magnet materials. In these proposals, the rotor structures have employed permanent magnet segments buried within the rotor body and a suitably shaped conductive cage. However, these proposed structures are not suited to quantity production, because of the intricate shapes required for the individual laminations and the need either to insert the magnets after the conductor structure is die cast, or to avoid excessive thermal stresses on the magnets during die casting. Furthermore, if the rotor is to be skewed, each magnet must be made of several segments assembled along the length of the motor, thus increasing the assembly time.

In accordance with this invention, there is provided a permanent magnet motor which comprises a rotor having a cylindrical core, a plurality of permanent magnets mounted to the surface of the cylindrical core, and a metal layer applied to the surface of the rotor over the permanent magnets.

The applied layer is effective in holding the permanent magnets in place on the rotor core, enabling the motor to be used at high speeds. The layer may be magnetically permeable (e.g. mild steel) or non-magnetic and of high conductivity (e.g. copper or aluminium) and there may be two or more layers. Preferably there is an inner layer of permeable material, e.g. steel, and an outer layer of high conductivity material, e.g. 30 copper.

The motor may be used also (or instead) as a self-starting (line-start) synchronous motor. Starting torque is developed by interaction between the rotating magnetic field, in the air gap between the stator and rotor, and electrical currents induced in the layer or layers surrounding the permanent magnets. If the applied layer, or one of the layers, is of magnetically permeable material, the presence of this layer reduces the magnetising component of the line current,

thereby reducing the starting current. The magnetically permeable layer contributes to the starting torque and so enhances the start-up performance of the motor. The permeable layer causes some of the magnet flux to be short-circuited, but 5 this is compensated to some extent by the fact that the magnets operate at a higher flux density point on their demagnetisation characteristic.

The permanent magnets preferably comprise rare earth high energy materials, e.g. samarium-cobalt or neodymium-iron-10 boron.

An embodiment of this invention will now be described by way of example only and with reference to the accompanying drawings, in which:

FIGURE 1 is a cross-section through the rotor of a 15 synchronous motor in accordance with the invention; and

FIGURE 2 is a graph to show typical variations with speed of the components of torque acting on the rotor during run-up to synchronous speed.

Referring to Figure 1 of the drawings, there is shown 20 the rotor of a four-pole motor in accordance with this invention. The motor has a conventional polyphase stator, typically a three-phase stator (not shown). The rotor comprises a cylindrical core 10 which may be laminated or solid: in the latter case, the core may be machined or cast. 25 Four alternately-poled permanent magnets 12, in the form of thin, arc-shaped shells, are mounted to the surface of the core 10 and in the example shown fit together with no gaps between them. A first layer of material 14 is disposed around the assembly of permanent magnets 12 and a second layer of material 30 16 is disposed over the layer 14.

In the example shown, the inner layer 14 comprises a cylindrical sleeve of high permeability material, e.g. mild steel, which is applied by freeze-fitting so as to firmly embrace the underlying magnets 12 and hold them to the core 10. 35 The outer layer 16 comprises a cylindrical sleeve of high conductivity material, e.g. copper, also applied by freeze-fitting. The inner and outer layers 14,16 may be of different thicknesses, each typically in the range of 1 to 4 mm. The permanent magnets may comprise, for example, samarium-cobalt

or neodymium-iron-boron, typically 2 to 4 mm thick.

In use as a self-starting (line-start) synchronous motor, a starting torque  $T_i$  is developed by interaction between the rotating magnetic field, established by the stator, and 5 electrical currents induced in the layers 14,16 surrounding the assembly of magnets. As the rotor starts to turn, the permanent magnet flux induces slip frequency emfs and currents in the stator windings. The torque  $T_m$  (magnet torque) associated with these currents opposes the induction 10 accelerating torque  $T_i$  during run-up. The net torque  $T_a$  which accelerates the rotor towards synchronous speed is given by  $T_a = T_i - T_m$ .

Figure 2 shows a typical variation with speed of the three components of torque  $T_a$ ,  $T_i$  and  $T_m$ . After 15 synchronisation, the induction torque  $T_i$  vanishes and the synchronous magnet torque reverses its role and becomes the sole source of torque. The motor's synchronous pull-out torque is proportional to the flux produced in the air gap by the permanent magnet assembly. However, this air-gap flux also 20 tends to set the general level of braking torque  $T_m$ : satisfactory run-up performance requires that  $T_m$  must be less than the induction torque  $T_i$  up to a speed just less than synchronous speed, depending upon the load inertia. The induction torque may be increased by increasing the thickness 25 of the metal layers 14,16 surrounding the permanent magnet assembly.

The application of the first layer of high permeability material 14 to the surface of the magnet assembly effectively reduces the air gap, thus increasing the strength of the 30 magnetising field at the rotor surface. The magnetising field induces currents, mainly in outer layer of high conductivity material 16. Although the inner layer 14 diverts some of the magnetic flux away from the air gap, this is compensated for (at least partially) by the magnets being operated at a higher 35 flux density point on their demagnetisation characteristic.

Claims

- 1) A permanent magnet motor which comprises a rotor having a cylindrical core, a plurality of permanent magnets mounted to the surface of the cylindrical core, and a metal layer applied to the surface of the rotor over the permanent magnets.
- 2) A permanent magnet motor as claimed in claim 1, in which the metal layer is magnetically permeable.
- 3) A permanent magnet motor as claimed in claim 1, in which the metal layer is non-magnetic and highly conductive.
- 10 4) A permanent magnet motor as claimed in claim 1, in which the metal layer comprises inner and outer layers.
- 5) A permanent magnet motor as claimed in claim 4, in which the inner layer is magnetically permeable, and the outer layer is highly conductive.
- 15 6) A permanent magnet motor as claimed in claim 5, in which the inner and outer layers are of different thicknesses.
- 7) A permanent magnet motor as claimed in any preceding claim, in which the permanent magnets comprises rare earth high energy materials.
- 20 8) A permanent magnet motor substantially as herein described with reference to the accompanying drawings.

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Examiner's report to the Comptroller under  
Section 17 (The Search Report)

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Relevant Technical fields

(i) UK CI (Edition 1 ) H2A (AKC2, AKC6, AKC1, AKH2)  
(ii) Int CI (Edition 5 ) H02K 01/02, 01/04, 01/27,  
                          ) 01/28

Search Examiner

J COCKITT

Databases (see over)

- (i) UK Patent Office  
(ii)

Date of Search

28 JULY 1993

Documents considered relevant following a search in respect of claims

1-8

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2204742 A (AISIN) see whole document	1, 2, 3, 7
X	GB 2172443 A (DOWTY) see pages 1 lines 17-25	1, 3
X	EP 0212552 A2 (KOLLMORGAN) see page 1 lines 15-20	1, 2
X	US 4625135 A (GARRETT) see column 4 lines 57-63	1, 3, 7

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Category	Ident. of document and relevant passages - 6 -	Relevant to claim(s)

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X: Document indicating lack of novelty or of inventive step.

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